TROPICAL AGRICULTURE

THE OFFICIAL JOURNAL OF THE
IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

VOL. XXII No. 10 OCTOBER, 1945 PRICE 6d

CONTENTS

The Ideal Climate 177

Review 178

(II) Solomon Islands 179

Incompatibility in Amazon Cacao 184

Inter-Specific Pollination in Theobroma ... 188

The Role of Calcium in Plant Nutrition ... 190

Biology and Agriculture in the Postwar World 191

Miscellaneous Notes 195

Chemical Notes 196

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

Cables :: "Stomata." | Phone :: 0365

TROPICAL AGRICULTURE is published monthly at the Imperial College of Tropical Agriculture, St. Augustine, Trinidad, West Indies. Advertisement and Subscription rates can be obtained at the College from the Editor, or from the Secretary of the College, Grand Buildings, Trafalgar Square, London, W.C. 2, England. The Editor will be glad to consider authoritative articles for publication. It is understood that opinions expressed or recommendations made in signed articles or in articles of which the source is named are those of the author and do not necessarily represent the policy or opinion of the College Authorities. Increasing numbers of inquiries are being received from the various parts of the tropics which can be answered only by persons possessed of an intimate knowledge of local conditions. Enquirers should first satisfy themselves that their local Department of Agriculture is not able to supply them with the desired information before communicating with us. Correspondence which will be replied to is invited on all other matters pertaining to tropical agriculture, science and development.

THE IDEAL CLIMATE

THE interesting question of what constitutes an ideal climate is discussed in an article by Professor David Brunt, F.R.S., appearing in *Nature**. Professor Brunt gives as his opinion that the ideal climate can be defined, provided we have a clear statement of the idea underlying the *ideal;* and provided we avoid the common error of regarding the climate in which it is pleasant to spend a summer holiday as the ideal climate in which to live permanently, and to do one's work.

Before we can determine the ideal climate we must, in fact, know for what degree of activity the climate must be ideal. Clearly the ideal will not be found either in the very cold polar regions or the very hot tropical regions. In a paper published some two years ago, Professor Brunt endeavoured to solve the first stage of the problem by postulating that it should be possible for a lightly clothed man to walk at four miles per hour in the sunshine without sweating, and to sit in the sunshine, or stand or sit in the shade or indoors doing light work, without shivering. With relative humidity of about 60 per cent., the temperature to fit this prescription will be between 66° and 68°F., and the optimum is thus 67°F. For the nude man the optimum temperature will be about 4° higher, say 70°-71°F.

Major S. F. Markham, in his book "Climate and the Energy of Nations", has directed attention to the fact that, on a world map of annual mean temperatures, the 70° isotherm passes through, or close to, all the centres of early civilizations in Egypt, Palestine, Assyria, Sumeria and Persia, and not far north of Mohenjodaro, the centre of the early civilization in the valley of the Indus. Thus the early civilizations arose in regions where the mean temperature of the year is now, and probably was then, 70°F. or very near it; and as they were founded by men who wore so little clothing that we may regard them as nude, we may take this as a confirmation of the estimate given above of the ideal temperature for the nude man.

An annual mean temperature of 70°F. would mean a summer temperature well above the limit, and a winter temperature well below it, so that the summer afternoons would be too hot, and the

*Abstracted from "Climate and Human Comfort", by Prof. David Brunt, F.R.S., Imperial College of Science and Technology, London.—*Nature*, Vol. 155, No. 3941, 562-564, 1945.

winter nights too cool, for comfort. With the development of methods of indoor heating in winter, the optimum conditions would shift to climates where the summer heat was less extreme; but the winter cold not such as to make indoor heating impossible, as exemplified in ancient Greece, and still more notably in the Roman Empire. With the fall of the Roman Empire, indoor heating became far less common, and almost died out, and the next major civilization, the Muslim, was again in the region of the 70°F. isotherm. Later on, in western Europe, as indoor heating developed, and houses once again became weather-proof, civilization began to make rapid strides.

We can now go a stage further, and state that for a healthy and active life the climate must be such that the mean temperature of the hottest month shall not exceed 70°F., or at most, 75°F., while the coldest month of the year shall not be so cold that it becomes difficult or expensive to maintain a comfortable temperature indoors. Markham (*loc. cit.*) states that when a white man migrates to a country where the mean temperature of the hottest month of the year exceeds 75°F. he finds that, whereas he and his children may be able to tolerate the changed conditions, his grandchildren will show a marked loss of energy and of mental and physical efficiency. Markham suggests that the 'poor white' problem which has arisen in many hot countries is a result of migration to unsuitable climatic conditions. It is unlikely that any simple hard-fast rule can afford a solution of the problem of desirable climates. Some allowance must be made for the effects of low relative humidity and of high wind speed, in modifying the disabilities of hot climates.

An examination of world maps of mean temperatures for each month of the year shows that only a very small fraction of the land areas satisfies the condition that the hottest month of the year has a mean temperature not above 75°F., while the coldest month of the year has a mean temperature not below freezing point. The largest single area satisfying these conditions is that part of western Europe which includes the British Isles, France, Northern Spain, Switzerland, Germany, the Netherlands, Denmark, and a strip along the south-western shores of Scandinavia. Within this area, there is a higher level of health and prosperity than in the neighbouring regions.

Markham quotes a considerable volume of statistics relating to health and prosperity for different countries, showing the lowest death rate and the lowest infantile mortality for the years 1926-35 to be those of New Zealand, the country which Professor Brunt regards as having the best climate of all countries in the world. Over most of New Zealand the mean temperature of the hottest month lies between 62° and 70°F., and that of the coldest month between 45° and 52°F. We might compare these figures with the corresponding figures for the British Isles, where the July mean temperature lies between 58° and 62°F., while the mean temperatures of the coldest month of the year lie between 39° and 44°F. In the British Isles, temperature readings above 90°F. are infrequent, and values exceeding 95°F. are decidedly rare, being generally confined to the inland regions of the southern half of England. In the British Isles the highest temperature recorded during a month may exceed the mean for that month by about 20°F. in winter, and by about 30°F. in summer, while the lowest temperature recorded may fall below the mean of the month by about 30°F. in winter, and by about 20°F. in summer.

REVIEW

LAM, H. J. (1945): Fragmenta Papuana (Observations of a naturalist in Netherlands New Guinea).

Sargentia, *V*, pp. 196. Translated from the Dutch by Lily M. Perry, pub. Arnold Arboretum of Harvard University, 1945.

Dr. Lam was Botanist on the Van Overeem expedition into the central mountains of Dutch New Guinea in 1920-21. The present work comprises a reprint of his writings on that expedition, published originally in Dutch in 1927-9 and here tranlsated into English by Lily M. Perry.

The first Fragment surveys the history of the exploration of the Mamberamo River with special reference to the Van Overeem and Kremer expeditions of 1920-22. The second gives some meteorological data, the third to sixth are principally botanical while the seventh and last primarily concerns the customs and behaviour of the Timorini, the natives of the remote mountain valleys.

Clearly, the work as a whole is a mixture and this applies also to the individual botanical sections. One finds floristic description cheek by jowl with rather vague ecological comment, topographical and geographical notes alongside phytogeographical speculation, remarks on travel and scenery along with observations of the birds and other wild animals. Thus, while the whole makes most interesting reading and is altogether in the best Naturalist-Traveller tradition, the information relating to any particular topic is woefully scattered and difficult to locate.

Most of the figures are good though surely English annotations could have been arranged where necessary. The important Map A is unfortunately poorly drawn and difficult to interpret. The text is excellent throughout and contains commendably few typographical errors. The translation, too, seems excellent and L. M. Perry is to be congratulated on avoiding almost all those awkward un-English phrases that so commonly appear in translation.

N.W.S.

(II) SOLOMON ISLANDS

BY

C. Y. SHEPHARD

(*Carnegie Professor of Economics, Imperial College of Tropical Agriculture*)

History.—The Solomon Islands were discovered in 1568 by the Spaniard, Alvaro de Mendaña, who had set out on a voyage of exploration from Peru. The contrast with Peru led the explorer to indulge in a fanciful description of the unparalleled wealth of the Solomons. Attempts to colonise the islands were punctuated by a grim series of murders. The islands proved an irresistible temptation to the 'black birders' in their search for cheap labour for the canefields of Queensland and Fiji. The British Protectorate was first proclaimed in 1803 over the Southern Islands and the others were added in 1898, 1899 and 1900. Bougainville Island, though geographically part of the Solomon Group, is not included in the Protectorate; it remained in German possession until 1914 and became part of the Territory of New Guinea mandated to Australia in 1920.

Geography.—The Protectorate is situated between the parallels of 5° south and 12° 30′ south and the meridians of 155° and 170° of east longitude, and consists of a double chain of elongated islands running roughly parallel in a north-westerly and south-easterly direction. The larger islands are mountainous, and of volcanic origin whereas the clusters of numerous small islands are of coral formation. The larger islands are Choiseul, Ysabel and Malaita, in the northern chain, and Vella Lavella, Kulambangara, New Georgia, Russell, Guadalcanal and San Cristoval, in the southern chain. The highest peak in Guadalcanal rises to 8,000 ft. and there are peaks up to 4,000 ft. on some of the other islands.

Climate.—The climate is humid and enervating and shows little variation of temperature throughout the year. The cooler, or south-east trade

winds, last from April to November, and the hotter or north-west season, from November to April. The rainfall is heavy generally, but varies considerably from month to month, from year to year and from island to island. January, February and March, are usually the wettest months but there is no reliable or well-defined dry season. The average annual rainfalls range from about 100 inches to over 200 inches in different districts.

Population.—The natives of the Protectorate are mainly of Melanesian stock, except in some of the outlying islands where Polynesians predominate. The total population at the last census (1931) was 94,000, of which natives accounted for 93,000. The total land area of the Protectorate is approximately 11,000 square miles. Two-fifths of the native population live in Malaita which is considered comparatively poor in natural resources. There are few coconut plantations in Malaita and this island provides the majority of the plantation labourers for the Protectorate.

Native Organization.—Native organization is primitive and there is no hereditary ruling class. The natives are divided into small clans, each observing its own customs and generally with no allegiance to any higher native authority. The elaborate social organization characteristic of Fiji and Tonga does not exist in the Solomons. Similarly, there is no common native language, and each village or group of villages has its own dialect, unintelligible often to its immediate neighbours, and there may be as many as 20 or 30 different dialects spoken in the one island. Conversation between Europeans and natives, and between natives speaking different dialects, is conducted in a crude form of pidgin English. The natives generally live on the foreshore, on small islands or in the hills. The natives seldom appear to congregate in large villages except under missionary influence, and the majority of the families in the interior of the larger islands lead an isolated existence.

Vegetation.—The natural vegetation of the islands is a dense tropical rain forest. On the large island of Guadalcanal, there is a level coastal strip of bush and grass covered plain, up to 10 miles in width, between the central hills and the north coast.

Food.—Imports of food per head of population are small and the bulk of such imports is supplied as rations to plantation and other wage-paid labour. (Table I.) The majority of the native agriculturists depend upon their own gardens for food, the staple crops being taro, sweet potato and yam (including pana). In addition, tree cabbage, bananas and plantains, pineapple and paw paw are grown in small quantities in many gardens. Poultry and pigs (both wild and domesticated) are consumed in small numbers. Few cattle are kept by natives and no cow's milk is normally consumed. There are many supplementary articles of diet either collected or cultivated. Both "salt water" and "bush" people consume fish, the latter bartering vegetables for fish and other sea foods. Many natives possess coconut groves, and the nuts are used for food or for the manufacture of copra for export. Native diets exhibit little variety and are sometimes inadequate. Agriculturists practice a system of shifting cultivation. Land is almost everywhere abundant, but the process of felling and clearing forest every one or two years is a laborious undertaking for which, at present, there is no satisfactory alternative.

TABLE 1

Principal Imports

Value in £*

Commodity	1935-36	1940-41
Rice	14,346	12,194
Flour	2,769	3,629
Biscuits	3,793	2,757
Sugar	2,153	2,360
Preserved Meats ..	6,856	5,721
Beer	1,776	1,604
Other Foods	5,530	5,358
Tobacco	8,561	7,911
Machinery	5,204	14,870
Hardware	3,379	3,146
Paints	1,957	1,426
Timber	2,709	2,948
Kerosene	3,705	1,926
Motor Spirit	3,967	2,499
Bags and Sacks ..	10,098	5,508
Drapery, piece	5,188	8,457
Drapery, other ..	4,630	5,997
Drugs	3,237	4,159

* Australian.

Land Tenure.—Some of the earlier European settlers obtained freehold title to areas of land by purchase from the native owners, and there are a few large blocks secured in earlier days under 999 years' lease. Since 1914, however, land has been obtainable only under lease limited to 99 years for agricultural purposes but subject to renewal. Native ownership is recognised of unalienated land classed as "native land," that is, "land owned by natives or subject to the exercise by natives of customary rights of occupation, cultivation or other uses". All other unalienated land, termed "public land" is the property of the Crown. The system of native land holding is communal, with individual rights of cultivation. There is no shortage of land for native use and large areas are used only for hunting or for gathering forest produce.

European Plantations.—About 400,000 acres out of a total of 7,000,000 acres have been alienated to non-natives. Some 63,000 acres have been developed, mostly (62,000 acres) under coconuts

with a small area (300 acres) under rubber, ivory nuts and cocoa. Of the alienated land, 361,364 acres are freehold or held under occupation licence (999 years), 47,390 acres are held under Crown lease and 5,555 acres under lease from native owners. European enterprise has been restricted almost entirely to the coconut industry. The annual export of copra is normally about 21,000 tons. Messrs. Lever's Pacific Plantations Proprietary Limited, is the principal single producer of copra. This Company's output is exported to Australia where it is used in the Company's factories. The balance of the copra production is shipped to Europe and sold on the open market. The areas under coconuts and the production of copra during 1937, are shown for the various administrative districts in Table 2. These data do not include native cultivation. The normal labour requirement is about one labourer to 10 acres and the average number of labourers employed pre-war was about 5,000. The bulk of the labourers were recruited from the island of Malaita under a contract system, with a maximum term of 2 years. The employer was required by law to feed, clothe and house the labourer, to provide him with medical attention and to repatriate him on the expiration of his contract. Minimum wages were fixed by law at 10/- per month.

TABLE 2

Coconuts (1937)*

District	Acres	Tons
Ysabel (including Russel Island)	19,347	7,793
New Georgia, Gizo District	16,453	4,567
Guadalcanal	14,484	4,327
Shortland Island ..	6,302	1,654
Malaita	2,564	728
(San Cristoval) East Solomon Islands ..	2,582	661
Tulagi and district ..	487	195
Santa Cruz	90	—

* Excluding native cultivation.

Coconuts are planted on the low-lying coastal fringe of the larger islands. Some of the smaller coral islands are devoted exclusively to coconuts. Yields are said to average about 6 cwt. of copra per acre per annum. These yields are low, due largely to premature nut-fall. The principal cause of immature nut-fall is the pest *Amblypelta cocophaga* for which no effective parasite or predator has yet been found. In the Russel Group of islands, which is free from this pest, yields of copra are said to average about 10 cwt. per acre, and post-war development of the coconut industry will probably be concentrated in this Group.

Livestock.—The cattle population of the Solomons before the war was approximately 16,000 head, the majority being maintained on the coconut plantations where they were used to control weed growth. Cattle provide meat rations for the labourers and this perquisite was one of the principal attractions to labourers on the plantations. A few cows only were kept to supply milk to the small European community.

TABLE 3

Livestock (as at 31st March, 1937), Head of

District	Cattle	Horses	Mules	Pigs	Goats	Sheep
Guadalcanal ..	6,099	134	11	—	195	—
Ysabel	4,949	57	29	67	6	—
Gizo (New Georgia)	3,113	21	8	141	21	—
Shortland Island ..	758	—	—	157	264	80
Malaita	581	13	—	20	50	—
Eastern Solomon Islands ..	400	3	—	18	—	—
Others	115	6	—	—	4	—

European pure bred cattle were originally imported and bred, but later Zebu were introduced and crossed with European breeds. It is estimated that the cattle population has been reduced by the Japanese and Allied Military Forces to 5,000 head, and the restoration of the cattle population to its former level will require several years of effort.

The most important disease of livestock in the Solomon Islands is the condition brought about by the continuous irritation by the buffalo fly *Lyperosia exigua*. The fly gained access to the Protectorate about 1925 by way of Bougainville, and all the main islands, except San Cristoval, are infested. Attempts made in other countries to control the fly by biological means have not yet proved successful.

Timber.—The islands of the Solomon Group are densely wooded. The exploitation of the forests has been confined to the island of Vanikoro in the Santa Cruz Group where the Vanikoro Kauri Timber Company, an Australian concern, cuts and ships kauri and other timbers to the Australian market in logs, and to the Shortland district where "Island cedar" has been cut and shipped in small quantities by a private individual. The forests in Vanikoro were surveyed some years ago by a Forestry Officer from Fiji but this survey covers only a small fraction of the forests in the Protectorate. It is probable that a forestry survey would reveal other and larger areas of forest capable of commercial exploitation, provided capital and labour are available.

Ivory Nuts.—The ivory nut is the fruit of a species of sago palm, *Metroxylon solomonense* Becc., indigenous to the Solomons and which grows in swampy ground. The palm takes about 10 years to attain maturity, fruits but once, and

then dies. The palm grows wild but some small areas have been planted. The nuts are used in the manufacture of buttons. Small quantities are collected and exported.

Fisheries.—Fish is an important article of native diet, and it is customary for the "bush" native to exchange vegetables for fish caught by the "salt water" natives. There is little prospect of developing the fisheries for export purposes, but other sea products, notably trochus shell, green snail shell, turtle shell and bêche-de-mer have been exported from the Colony in small quantities.

Minerals.—Prospecting in recent years has established the presence in Guadalcanal of gold deposits which may prove sufficiently rich to attract the attention of mining interests. Systematic and intensive prospecting was in progress immediately before the Japanese military occupation of the island interrupted the work. Indications of gold have been reported from other islands of the Group as well as manganese, bauxite and other minerals. Lack of funds has prevented a systematic geological survey of the Protectorate.

TABLE 4

Values of Imports and Exports

Year	Imports	Exports
	£*	£*
1919-20	181,165	212,541
1920-21	324,754	336,546
1921-22	251,566	182,887
1922-23	188,771	231,698
1923-24	233,839	286,569
1924-25	231,040	331,211
1925-26	266,943	417,477
1926-27	296,721	451,994
1927-28	264,193	386,458
1928-29	295,141	436,158
1929-30	248,307	351,548
1930-31	215,269	304,310
1931-32	157,491	175,554
1932-33	168,261	189,888
1933-34	158,776	111,669
1935-36	150,163	198,358
1936-37 ..	190,967	331,438
1940-41	134,088	138,628

* Australian.

TABLE 5

Principal Exports

Values in £*

Products	1929-30	1936-37	1940-41
Copra	304,088	293,054	100,888
Trochus Shell ..	26,325	22,426	6,907
Timber	9,276	6,063	11,809
Ivory Nuts ..	8,232	4,263	909
Green Snail Shell..	2,411	2,156	638
Bêche-de-Mer ..	520	33	406
Miscellaneous ..	533	29	17,019
Totals ..	351,548	331,438	121,199

* Australian.

Pre-war Policy.—Pre-war financial policy dictated that the Protectorate should be financially self-supporting. This necessitated a policy of encouraging the influx of capital for the exploitation of the Colony in export crops. The profitable market for copra during the early part of the present century attracted large quantities of capital for the development of coconut plantations. Copra accounted for about 90 per cent. of the total value of exports and, directly and indirectly, was the most important source of public revenue. The slump in copra prices, which continued from 1930 onwards, was quickly reflected in public revenue and necessitated curtailment of public services.

Effect of the War.—All non-natives engaged in commerce and industry were evacuated from the Protectorate early in 1942 since when commercial production of copra has ceased. Many of the plantations have become invaded with bush and with a rich growth of volunteer palms from fallen nuts. The cost of rehabilitating the plantations will be heavy, especially in view of the severe reduction in the number of cattle, and it seems probable that those areas where premature nut-fall has seriously reduced yields will be abandoned. Enemy occupation of the western half of the Protectorate, and the subsequent military operations which resulted in its recapture, occasioned much damage to buildings and plantation equipment. The coconut plantations occupied the flat coastal areas and some have been cleared for the construction of air fields, while others are used as military camps. The present price of copra is high, but the labour force normally engaged on the plantations is now enrolled in the Solomon Islands Protectorate Labour Corps. The ability of the Protectorate to finance public services from its own resources depends in very large measure on the prosperity of the copra industry. The future of copra prices cannot be predicted with certainty, and in any event it seems desirable that an attempt should be made to broaden the economic resources of the Protectorate.

The presence of large Military Forces in the Protectorate has recently brought temporary prosperity to a large proportion of the population. Large numbers of men are serving in the Labour Corps from which they receive clothing, rations and pay. Substantial sums have been received from the sale of curios and souvenirs to the troops. Native gardens have been neglected because of the absence of men on service. The dislocation

of the copra industry will seriously curtail public revenue. There is urgent need however, for an expansion and improvement of the Public Services which have hitherto been starved for lack of funds.

Education.—Government has played no part in the education of the natives beyond arranging for an expert investigation. Education has hitherto been conducted entirely by the various mission bodies whose funds are too limited for them to reach more than a fraction of the population, and there are sections without access to any form of school. The absence of a comprehensive and sound system of elementary education is reflected in the difficulty in securing suitable candidates for subordinate posts in the Public Service. The problem of education, like that of every other Public Service, is complicated by the scattered nature of the population and the absence of roads into the interior.

Medical.—The Medical Service hitherto provided has been pitifully inadequate. The Solomon Islands participate in the training given at the Central Medical School in Fiji but students from the Solomons have been handicapped by the inadequacy of their basic education and a lack of proficiency in English. The consequence is that the Solomon Islands have been unable to participate as fully as intended in the Central Medical School. The medical staff has been too small to achieve much in the fields of public health, child welfare and sanitation. The training of native nurses has also been hindered by lack of essential educational facilities. Yaws and malaria are prevalent throughout the Protectorate. The Central Hospital at Tulagi has been completely destroyed as a result of military operations.

Roads.—There was practically no public road system in the Protectorate prior to the war. Rudimentary roads existed within the coconut plantations to facilitate the collection and transport of produce and labourers. Outside the plantations only native trails existed. The lack of roads has seriously hindered both the development of contact between Government Officers and the natives, and the transport of produce from the interior to the coast. Good motorable roads have been constructed in those islands under military operation but the maintenance of all these roads, and more particularly the bridges, will prove an impossible financial burden on public revenue after the war. Travel from island to island by Government Officers has necessarily been by sea, and sea has generally provided the most convenient means of travelling from place to place on the large islands, the journey to the inland village being completed on foot over native trails. A very large proportion of an officer's time and energy is inevitably absorbed in mere travel.

Overseas Communication.—The economic development of the Protectorate has been handicapped by the infrequent facilities for communication between the various islands comprising the Protectorate and overseas markets. Exports have necessarily been confined to products capable of withstanding a long storage within each island and heavy costs of transport to markets.

Native Agriculture.—Natives at present practice a system of shifting cultivation. Their tools are primitive and usually consist of an axe, a cutlass and a planting pole. Food supplies are deficient and ill-balanced and have sometimes been inadequate in quantity. The natives are primitive and backward, and progress will be made only as a result of sound and careful experimentation and patient extension work. Government has hitherto maintained an entomologist and an agricultural officer but no facilities have been provided for the development or improvement of native crops. There is an Agricultural Advisory Committee whose effectiveness has been limited by lack of staff. The small amount of experimental work hitherto conducted, has been done mainly by the Missions or by individual Europeans. There is, however, abundant scope for the development and improvement of native agriculture, and there are large areas of fertile soil available for native use.

INSECT PEST RESISTANCE IN PLANTS

The Imperial Bureau of Plant Breeding and Genetics, Cambridge, has issued a Bibliography on Insect Pest Resistance in Plants (1s. 6d.). The sources drawn upon include publications from the British Commonwealth, the main European countries, the United States and various South American countries, the U.S.S.R. and Japan. In all, there are more than 550 references arranged according to subject, the chief of these being cereals, roots and tubers, cotton, sugar-cane, fruits and vegetables. Nematodes are dealt with in a special section. Many of the publications included have been abstracted in *Plant Breeding Abstracts*, and in many instances the original publications cited are available at the Bureau or in some co-operating library, and further information can therefore, if necessary, be obtained on application to the Bureau. It is believed that the bibliography will be of practical assistance not only to the breeder and the geneticist, but also to all who are interested in the solution of the important problem of the fundamental basis of insect or nematode resistance among crop plants.—(*Nature*, Vol. 155, No. 3924, 1945.)

The Editor requests that any subscriber who fails to receive *Tropical Agriculture* regularly should communicate with him immediately in order that the matter may be rectified.

INCOMPATIBILITY IN AMAZON CACAO

BY

A. F. POSNETTE

Introduction

Between November, 1943 and May, 1944, the writer was in Trinidad collecting pods of all available cacao types for despatch to West Africa. Owing to the prevalence of cross-pollination (10), it was desirable to control pollination in order to ensure that West Africa should receive certain distinct types uncontaminated with characters from others. In the course of hand-pollinating the Amazon types of cacao introduced to Trinidad by Pound (14), a form of self-incompatibility was discovered which differs from that known in Trinitario cacao. It was not possible to investigate this problem fully, but the facts established are regarded as sufficiently important to be placed on record.

In 1937, Voelcker (18) reviewed the literature on self-incompatibility in cacao, concluding that "only the elementary bare facts of its existence have been investigated". He also showed (16, 17) that it is a permanent condition in the Trinitario* type of cacao, and that self-incompatible trees are incompatible with each other, but compatible both as male and female parents with self-compatible types. Posnette (9) showed that certain self-incompatible Trinitario trees are not compatible with all self-compatibles, and that incompatible pollen on the stigma reduced setting by compatible pollen, unless the latter had some hours start or a shorter path for the tubes to travel. Cope (2) confirmed Voelcker's results, and also demonstrated (4) that the failure occurs after fertilization in Trinitario cacao, and is not due to slow growth of the pollen tubes. This raises doubt about the validity of the term "incompatibility" for this type of sterility, but Crane and Lawrence (5) prefer it to "self-sterility" when neither pollen nor ovules are defective.

Posnette (9) has reported self-incompatibility in the Amazon* type known as "West African Amelonado", in which Voelcker (16) and he agree that it is extremely rare. The wild type introduced by Myers (7) from Surinam is self-compatible; no self-incompatibility has been reported from Bahia where mainly Amazon cacao is grown. But in the Trinitario mixture found on estates in Trinidad and Venezuela, in the descendants of Criollo types introduced to Trinidad from Nicaragua and South America, and in the "Wild Cacao" found in the forests of Trinidad and Tobago (believed to be relics of pre-nineteenth century Criollo cultivation) a large proportion of the trees are self-incompatible, being compatible only with pollen of self-compatible trees. (Seventy out of the 100 I.C.S. clones are probably self-incompatible.) Self-incompatibility has therefore been assumed to be a characteristic of the better quality ("Fine") types of cacao, and Cheesman (1) has suggested that it might have originated through the recent mixing of previously distinct populations.

*Trinitario is the term applied to a highly variable type of cacao of doubtful affinities; it includes the bulk of the "Fine" quality cacao now in cultivation. "Amazon" is the term used to describe the much more uniform type of cacao which constitutes the "Ordinary" quality cacao produced by West Africa and Brazil; as used here "Amazon" is synonymous with *Th. leiocarpa* Bern. as used by recent writers in error. Cheesman (1) has pointed out that Bernouilli's original description of *Th. leiocarpa* includes white beans—a criterion of Criollo, or true *Th. cacao*.

Amazon Material

Pound (14) has described the range of pod-types he found on the Amazon and its tributaries. By pod-characters he was able to distinguish different cacao populations; that these are distinct and have developed in at least partial isolation, is indicated also by divergence in their vegetative and floral characters, which have not previously been described. Since the distinctness of these different populations is relevant to the pollination results to be described in this paper, some new observations are included here.

A previously unrecorded character was observed in the flowers of some Amazon types. All cacao flowers of West African Amelonado, Trinitario and Criollo types inspected have stamen filaments usually unpigmented, very occasionally faintly tinged with purple. All the Ecuador type trees examined at the Imperial College of Tropical Agriculture have pigmented filaments, the colour varying from pink to maroon, and this character is also present in some upper Amazon populations. It is not associated with pigment in the leaf or on the pod.

When plants budded from the seedling progeny of the Amazon trees were classified according to petiole-form and stamen-pigment, very few exceptions were found to the following descriptions. In these apparent exceptions, pod characters agreed with the identification by other characters, so possibly confusion between the abbreviations N.A. and P.A. had occasionally occurred.

Nanay River Type (sample of 80 trees)

The Nanay type has fan branches characterised by relatively short (less than 2 cms.) petioles in which the pulvini are not clearly separated until the leaf ages, when a shallow constriction may develop.

The stamen filaments are always pigmented to some degree, usually heavily.

Parinari River Type (sample of 40 trees)

The Parinari type has long petioles (2-3 cms.) with the pulvini separated by a long, deep constriction even when young.

The stamen filaments are not pigmented.

Iquitos Calabacillo Type (sample of 20 trees)

The type from an island near Iquitos has petioles intermediate between those of the Nanay and Parinari types; the construction between the pulvini is usually short and shallow.

The stamen filaments are pigmented.

Ecuador Type

In 1938 Pound (14) introduced seedling progeny from eighty trees resistant to witches' broom on estates on the coast of Ecuador. Some of these seedling bear red pods indicating a pollen parent of Trinitario origin, but most of them closely resemble, upper Amazon types in pod characters, pigmented stamens, petiole shape, glabrous young shoots, growth habit, and type of self-incompatibility. This also applies to earlier introductions from Ecuador to the Imperial College; although called "Cacao Venezuela" (E 1-5, E 221-240) and reputed to have originated from Trinidad, they show no affinities with Trinitario. This supports Pound's belief that most of the witches' broom resistant trees in Ecuador came from east of the Andes (15).

Pollination Results

Self-incompatibility

Self-pollination was done by hand (the flowers being covered with fine muslin the day before opening) on representative trees of the four types mentioned above growing at the Imperial College of Tropical Agriculture. No sets were obtained and this failure was first attributed to external causes, but when cross-pollination produced good setting, it became evident that self-incompatibility was the cause. A large proportion of the trees in the main collection of Amazon types at Marper Estate were then tested, with the result that one set was obtained on only one tree (Nanay 162), and since in this case the flower was not protected, the possibility of cross-pollination cannot be excluded.

This complete self-incompatibility in the majority of these Amazon types was unexpected. Their flowering is less profuse than that of most of the self-incompatible Trinitario types, while in their high rate of natural setting they resemble self-compatible trees.

Cross-compatibility

The high yield of these self-incompatible types in their Amazon environment, as described by Pound (14), would be expected only if they were cross-compatible. Previous work has established that all self-incompatible Criollo and Trinitario trees in Trinidad are incompatible with one another, but usually compatible in reciprocal crosses with self-compatible trees. As shown in Tables I and II, hand-pollination revealed that many of the self-incompatible Amazon types are compatible with one another, this compatibility usually being shown in reciprocal crosses. Some crosses between self-incompatible Amazon types are shown to be incompatible, and there appears to be more cross-incompatibility within a population than between different populations; this is perhaps because some of the trees of each type at the College are from the same progeny.

TABLE I

Cross-compatibility in Self-incompatible Amazon Types

		Nanay				Parinari				Iquitos			
		31	32	33	34	4	5	7	35	46	47	60	76
Nanay	31	S	C	–	–	?I	–	–	–	–	–	–	–
	32	C	S	C	I	–	–	C	C	C	–	C	C
	33	–	C	S	C	C	C	–	–	?I	C	C	C
	34	–	I	C	S	–	–	C	–	–	–	C	–
Parinari	4	C	–	–	–	S	I	I	–	–	–	–	–
	5	C	–	–	–	–	S	I	–	–	–	–	–
	7	C	C	–	C	–	–	S	–	–	C	–	–
	35	C	C	–	–	C	–	C	S	–	–	–	–
Iquitos	46	–	C	–	–	–	–	–	–	S	–	I	–
	47	C	–	C	–	–	–	–	–	–	S	I	–
	60	–	C	–	C	–	–	–	–	I	I	S	–
	76	–	C	–	–	–	–	–	–	–	–	–	S

S = Self-incompatible pollinations } no sets from at least 10 pollinations
I = Cross-incompatible pollinations }
C = Cross-compatible pollinations; at least 25 per cent. setting
– = No pollination done

Note:—Continuous Self-incompatibility of N32 shown by 120 selfings from November, 1943 to May, 1944.

TABLE II

Cross-compatibility in Self-incompatible Ecuador Types

	1	2	5	222	223	224
1	S	I	C	–	–	–
2	I	S	C	–	–	–
5	C	C	S	–	–	–
222	–	–	–	S	C	–
223	–	C	–	C	S	C
224	–	–	–	–	C	S

S = Self-incompatible pollination } no sets from at least 15 pollinations
I = Cross-incompatible pollination }
C = Cross-compatible pollinations; at least 25 per cent. setting
– = No pollination done.

As shown in Table III, all the crosses made between Amazon and Trinitario types (most of the latter being Criollos with probably a few Trinitario genes) were compatible, although both parents are self-incompatible.

These facts suggest a tendency for self-incompatibility genes to differ in each Amazon population; between Amazon and Trinitario types this difference is complete.

TABLE III

Cross-compatibility between Self-incompatible Amazon and Trinitario Types

Trinitario Types	Amazon Types					
	Nanay		Iquitos	Ecuador		
	32	33	60	2	224	223
M.1 ..	C	C	C	–	–	–
M.188 ..	–	–	–	–	C	–
M.193 ..	–	–	–	–	–	C
I.C.S.97 ..	–	–	–	C	–	–

C = Fertile pollinations; at least 50 per cent. setting.

Mechanism of Self-incompatibility

There are important differences in the mechanism of self-incompatibility between cacao and Nicotiana, Petunia and temperate fruit crops. In the latter group, incompatibility is usually due to the inhibition of pollen-tubes carrying the same incompatibility factor as the style in which they are growing.

In an attempt to find out whether the mechanism of incompatibility in Amazon cacao is independent of pollen-tube growth, as shown by Cope (4) in Trinitario cacao, two preparations of sectioned ovaries of a Nanay type, 30 hours after pollination, were studied. Pollen-tubes had entered the embryo-sac; the contents could be interpreted to agree with Cope's figures, in which he showed that the failure of incompatible pollinations occurs after fertilisation. The sterility may therefore be caused by the inviability of either the zygote or the endosperm nucleus, but a more probable interpretation postulates a reaction of the maternal tissues to the incompatibility genes in the pollen-tubes or in the embryo. It seems doubtful whether inviability of a proportion of the ovules would check ovarian development since Pound (11, 13) has shown that the number of beans in a mature pod may be as low as half the number of ovules.

There is, however, in cacao an active mechanism of flower shedding (Pound 12). In incompatible pollinations, abscission may be delayed while ovarian development proceeds for as long as ten days; or shedding may occur as though the flower had not been pollinated (16). It seems probable that either the pollen-tubes or the fertilised embryo-sacs influence the maternal tissue to inhibit the abscission mechanism in compatible pollinations, while in incompatible pollinations this inhibition is lacking. It is tentatively suggested that the failure to inhibit the maternal mechanism of flower-shedding occurs when the pollen-tube carries the same incompatibility gene as the maternal tissue.

It is impossible to go further than to suggest the possibility of this mechanism of incompatibility in cacao, until we know much more about the inter-relations and inheritance of incompatibility in the Amazon types, and about the behaviour of the pollen and of the zygote in incompatible pollinations. The only available data on the inheritance of self-incompatibility have been presented by Cope (3), who showed that a self-incompatible — self-compatible cross results in approximately equal proportions of self-incompatible and self-compatible progeny.

Discussion

The genetics of self-incompatibility in cacao is of considerable importance both from the practical plant-breeding view-point and in attempting to classify the many types in the species. An illustration of the practical side is the fact that these Amazon types were introduced as open-pollinated pods from trees selected for resistance to witches' broom disease. Had the parent trees been self-compatible there would have been a possibility that the pods resulted from self-pollination, and hence that the progeny might inherit resistance. Since the progeny are self-incompatible it is almost certain that their parents were also, and these progeny would therefore be the result of cross-pollination with trees whose resistance is unknown.

Unlike Trinitario clones, however, it should be possible to obtain good setting by interplanting two self-incompatible Amazon clones in the absence of self-compatible trees.

In discussing the relationships between the various types of cacao, Cheesman (1) has mentioned the self-incompatibility of Trinitario cacao as supporting the "hybrid" nature of this variable type. Now that self-incompatibility has been shown to be more common in some Amazon than in Trinitario types, this argument, which I also used (9), is untenable; incompatibility must be regarded as characteristic of the species, and probably of the genus *Theobroma*.

With the present paucity of facts about the origins and genetics of cacao, theories are inevitable. It is hoped that the Gold Coast collection, largely derived from the pollinations listed in the tables, will throw some light on the genetics of self-incompatibility. Meanwhile the following hypothesis is suggested to explain the unknown distribution of self-incompatibility in cacao. Present in the original cacao population in the "centre of origin", presumably on the upper tributaries of the Amazon, are a large number of different self-incompatibility genes (allelomorphic series) and one (or very few)

fertility genes. The trees are therefore predominately self-incompatible but cross-compatible as the figures show for the Trinidad introductions from this region.

The dispersal of cacao eastwards down the Amazon was not associated with cultivation; whereas man was probably responsible for its spread across the Andes and later northwards. If only a few pods at a time were transported through a series of migrations further and further from its origin, the number of incompatibility allelomorphs would be reduced at each stage. Since the cacao would be planted in groups of trees, self-incompatibility would not preclude fruiting, provided cross-fertile trees were included as pollinators. A stage would be reached where few different incompatibility genes remained in the population. Most of the self-incompatible trees would then be incompatible with one another, and fertile only with self-compatible trees. This is the condition of Trinitario Forestero in which the evidence suggests the presence of only a single self-incompatibility gene.

In passing down the Amazon Valley, with dispersal by animals, cacao trees would be scattered in the forest and cross-pollination made difficult. Myers (7) states that monkeys scatter cacao-seeds long distances in the forests of Surinam. Self-compatibility would therefore have great survival value, and would predominate in the types reaching Brazil and the Guianas. This would account for the predominance of self-compatibility in West African Amelonado, which probably came from Surinam; in the similar wild Surinam type found by Myers; in Maranhao and presumably in most other Bahia types. An interesting side-issue is the loss of stamen pigment and short petiole, neither of which characters seems to occur outside the upper Amazon populations and their descendants in Ecuador.

The origin of Trinitario cacao is still controversial; either it came from the Orinico or Colombia as an already variable type, or was synthesized in Trinidad by hybridization between a Central American Criollo and an eastern Amazon type. Some light might be thrown on this problem by a genetical proof that the type of self-incompatibility in Trinitario cacao could be derived from the self-incompatibility system in Amazon populations.

Summary

1. A description is given of a new floral character and of the petioles of some types of cacao introduced to Trinidad from the upper Amazon and Ecuador.

2. Hand pollination has demonstrated that a high proportion of these Amazon types are self-incompatible. They differ from self-incompatible Trinitario types in being cross-compatible.

3. The known distribution of self-incompatibility in cacao populations is discussed, and a theory advanced to explain it.

Acknowledgments

I am indebted to Professor E. E. Cheesman and Dr. F. J. Pound for many instructive conversations and for making available the plants used in this investigation. I am grateful to Mr. J. B. Hutchinson and Mr. B. L. Hancock for much helpful criticism.

This paper is published by kind permission of Mr. O. J. Voelcker, Director of the West African Cacao Research Institute.

References

1. Cheesman, E. E. (1944)—Notes on the nomenclature, classification and possible relationships of Cacao populations. *Trop. Agriculture*, XXI. 8. 144.

2. Cope, F. W. (1938)—Compatibility and fruit setting in cacao. Eighth Ann. Rep. Cacao Research, Trinidad.

3. Cope, F. W. (1938)—Some factors controlling the yield of young cacao II. Eighth Ann. Rep. Cacao Research, Trinidad.

4. Cope, F. W. (1939)—Studies in the mechanism of self-incompatibility in cacao, II. Ninth Ann. Rep. Cacao Research, Trinidad.

5. Crane and Lawrence (1938)—Genetics of garden plants. *Macmillan & Co., Ltd.*, London.

6. Myers, J. G. (1930)—Notes on wild cacao in Surinam and British Guiana. *Kew Bull.* (1930) 1. 10.

7. Posnette, A. F. (1937)—Incompatibility and pollination in cacao. Seventh Ann. Rep. Cacao Research, Trinidad.

8. Posnette, A. F. (1940)—Self-incompatibility in cacao. *Trop. Agriculture* XVII. 4. 67.

9. Posnette, A. F. (1944)—Pollination of cacao in Trinidad. *Trop. Agriculture*, XXI. 6. 115.

10. Pound, F. J. (1931)—The Genetic constitution of the cacao crop. First Ann. Rep. Cacao Research, Trinidad.

11. Pound, F. J. (1931)—Studies in fruitfulness in cacao. I.—A note on the abscission of the flower. First Ann. Rep. Cacao Research, Trinidad.

12. Pound, F. J. (1934)—Studies in fruitfulness in cacao. VII.—Ovule loss at fertilisation. Fourth Ann. Rep. Cacao Research, Trinidad.

13. Pound, F. J. (1938)—Cacao and witchbroom disease. Report of Trinidad Department of Agriculture.

14. Pound, F. J. (1943)—Cacao and witches' broom disease. Report of Trinidad Department of Agriculture.

15. Voelcker, O. J. (1936)—Self-incompatibility in cacao. Sixth Ann. Rep. Cacao Research, Trinidad.

16. Voelcker, O. J. (1937)—Self-incompatibility in cacao. Seventh Ann. Rep. Cacao Research, Trinidad.

17. Voelcker, O. J. (1937)—Cacao—A summary of literature since 1931. *Ibid.*

INTER-SPECIFIC POLLINATION IN THEOBROMA

BY

A. F. POSNETTE

Introduction

Like the previous paper on self-incompatibility in Amazon cacao (4), the following describes no more than the beginning of an investigation which was terminated prematurely by my departure from Trinidad. It is published to make available to other cacao investigators some results which may have important implications, in the hope that the collection and investigation of *Theobroma* species other than *cacao* will be stimulated.

In 1937, Posnette (3) used pollen of *Th. angustifolium* D. C. and of *Th. bicolor* H. B. K. in an attempt to induce pollen stimulation of flowers on self-incompatible trees of *Th. cacao* L. (Trinitario type). Flower shedding was not delayed by pollen of *bicolor*, and no pollen-tube growth was observed. Pollen of *angustifolium* germinated and delayed shedding, causing ovarian development. One pod grew nearly to maturity before being destroyed by fungal attack.

Although there may have been other attempts to hybridise *cacao* and *bicolor*, I can trace no published results of pollination between distinct species of *Theobroma*. (*Th. pentagona* is now regarded by Cheesman (2) as a type of *Th. cacao*.) The pollination experiments to be described were done at the Imperial College of Tropical Agriculture in the dry season of 1943-44. The loss of cherelles was therefore high, and most of the pods wilted when about one-third grown. It must be stressed that other pods on the trees wilted simultaneously with those resulting from hand pollination, indicating strongly that the loss of hybrid cherelles was due to physiological and not to genetical causes.

Flowers were considered "set" only if the cherelles were growing normally 14 days after pollination. Flowers of *Th. cacao* were protected with muslin, but flowers of other species were not, because no natural setting was occurring at the time of the investigation.

Th. cacao x *Th. angustifolium*

Only one tree of *Th. angustifolium* now survives in Trinidad. It is a layer from a tree introduced from Central America by J. H. Hart. Although the parent tree is said to have fruited, had it done so propagation by seed would have been a more logical method than by layering. This layer flowers profusely but has never set fruit. Inspection of the flowers showed that natural pollination was occurring to about the same extent as in Trinitario cacao, 2 per cent. of the flowers having abundant pollen on the style and stigma. Hand self-pollination was done at each flowering, but no setting followed. Fifty flowers of this *angustifolium* tree were pollinated with pollen from several neighbouring Trinitario trees; one set and ripened into a normal pod containing nine fully developed beans weighing 5 grams each. This pod was sent to the Plant Quarantine Station in Accra, Gold Coast, but the beans failed to germinate.* As the flower was not protected, this pod might be the result of self-pollination, but the evidence strongly supports the conclusion that the tree is self-incompatible.

TABLE I

Th. cacao x *Th. angustifolium*

Cacao type		Flowers pollinated with angustifolium	No. Set
AMAZON			
Ecuador ..	225	3	0
,, ..	226	3	0
,, ..	227	20	0
,, ..	231	3	0
,, ..	239	10	0
Nanay ..	31	7	3
,, ..	32	64	17
TOTAL AMAZON	7	110	20
TRINITARIO (near Criollo)			
I.C.S.	85	23	6
	M. 1	15	0
	M.109	25	19
	M.171	7	0
	M.182	11	6
	M.183	5	1
	M.184	7	0
	M.185	7	0
	M.186	20	0
	M.187	8	1
	M.188	7	0
	M.190	10	0
	M.195	15	0
	M.196	20	0
	M.198	5	4
TOTAL TRINITARIO	15	185	37

Pollen from this *angustifolium* tree was used to pollinate flowers of many of the *cacao* types in the College collection. As shown in Table 1. it was found that compatibility exists between *angustifolium* pollen and flowers of certain *cacao* trees which are probably of pure or nearly pure Criollo type. Compatibility with Amazon types appears to be rarer, but one Nanay tree gave

*Open-pollinated beans of *Th. angustifolium* from Dominica, B.W.I. proved extremely difficult to germinate in Accra; 3 germinated out of 69 beans planted from four pods received in good condition.

26 per cent. setting with *angustifolium* pollen. The cherelles developed normally for two or three months, but eventually all were lost from wilt.

Pollen of *Th. grandiflorum*, *Th. bicolor* and *Th.* (*Herrania*) *balaoense* was used on flowers of *Th. angustifolium* without success.

Th. cacao x *Th. grandiflorum*

The single tree of *Th. grandiflorum* produced few flowers. Ten flowers were self-pollinated and no sets resulted. This tree may be self-incompatible, but as this was the first time the tree had flowered, possibly its youth affected setting.

Table 2 shows that pollen of *grandiflorum* is partially compatible with flowers of some Amazon types of *cacao*.

TABLE 2

Th. cacao x *Th. grandiflorum*

Cacao type		Flowers pollinated with grandiflorum	No. Set
AMAZON			
Nanay ..	32	15	1
,, ..	34	6	0
Parinari ..	4	15	3
,, ..	5	10	0
,, ..	7	4	1
Iquitos ..	47	4	0
TOTAL AMAZON	6	54	5
TRINITARIO (near Criollo)			
I.C.S.	85	5	0
	M.109	10	0
TOTAL TRINITARIO	2	15	0

Th. cacao x *Th.* (*Herrania*) *balaoense*

During this investigation, eight seedlings of *Th.* (*Herrania*) *balaoense* were in flower of which only two set fruit, although all flowers examined had been pollinated. No sets were obtained from ten flowers self-pollinated by hand, so some, and possible all these *balaoense* plants are self-incompatible.

Pollen of *balaoense* was found to be compatible with flowers of all but two out of 19 Amazon and Trinitario trees tested. Microscopic examination revealed good germination of *balaoense* pollen and normal penetration of tubes down the cacao style.

Although wilt was severe, the greater number of sets obtained, and the earlier date at which pollination was done enabled a number of these pods to escape the wilt which eliminated the *angustifolium* crosses.

Nine pods of *Th. cacao* with *balaoense* pollen-parent were received at the Quarantine Station on the Gold Coast. In seven of these, all the beans contained an embryo, but the cotyledons were not enlarged and the bean was almost hollow. No facilities for embryo culture were available, and as anticipated, no germination was achieved in ordinary potting soil. In the other two pods, some beans appeared normal and have germinated; whether or not the seedlings are hybrids must await later investigation.

TABLE 3

Th. cacao x *Th.* (*Herrania*) *balaoense*

Cacao type		Flowers pollinated with Herrania	No. Set
AMAZON			
Ecuador ..	223	4	4
,, ..	224	2	2
Nanay ..	31	2	1
,, ..	32	30	9
,, ..	33	3	1
,, ..	34	1	1
Parinari ..	4	9	2
,, ..	5	10	4
,, ..	7	6	1
Iquitos ..	47	9	0
,, ..	60	14	7
,, ..	76	5	0
TOTAL AMAZON	12	95	32
TRINITARIO (near Criollo)			
I.C.S.	85	35	5
M.	1	13	4
M.	16	16	2
M.	17	9	2
M.	109	8	2
M.	181	2	2
M.	182	3	1
TOTAL TRINITARIO	7	86	18

Discussion

The discovery of some degree of compatibility between different (and probably distantly related) species of *Theobroma* may open a new field for the plant-breeder. This opinion is expressed with due reserve, since sterility problems must be expected in the hybrids; but at present the cacao industries in the New World are threatened by witches' broom disease, and in West Africa seriously menanced by virus diseases and Capsid pests (1). No record can be found of witches' broom attacking either *Th. angustifolium* or *Th.* (*Herr.*) *balaoense*, while Pound (5) believes that the whole *speciosum* group is immune to both witches' broom and black-pod (*Phytophthora* spp.).

To obtain resistance to these pests and diseases some sacrifice of yield and quality would be justified. Since vegetative propagation of cacao is now a commercial practice, a clone could be

developed from any hybrid seedling showing sufficient yield, quality and disease resistance. The immediate necessity is an extensive collection of wild species, so that their genetical relationships and commercial possibilities can be investigated. Self-incompatibility must be anticipated, and no species should be represented only by the progeny of a single tree.

Acknowledgments

I am grateful to Professor E. E. Cheesman for the use of the collection of *Theobroma* spp. grown by the Botany Department of the Imperial College of Tropical Agriculture.

This paper is published by kind permission of Mr. O. J. Voelcker, Director of the West African Cacao Research Institute.

References

1. Box, H. E. (1944)—The Salbergella Menace to Gold Coast Cocoa. Memo No. 9. Cocoa Research Station, Dept. of Agriculture, Gold Coast.
2. Cheesman, E. E. (1944)—Notes on the nomenclature, classification and possible relationships of cacao populations. *Trop. Agriculture*, XXI. 8. 144.
3. Posnette, A. F. (1937)—Incompatibility and pollination in cacao. Seventh Annual Report Cacao Research Scheme, Trinidad.
4. Posnette A. F. (1945)—Incompatibility in Amazon cacao. *Trop. Agriculture*. XXII. 10. 184.
5. Pound, F. J. (1938)—Cacao and witchbroom disease. Report of Dept. of Agriculture, Trinidad.

THE ROLE OF CALCIUM IN PLANT NUTRITION

Instances of calcium deficiency in plants are seldom recorded in this country, although it seems likely that poor growth and marginal blanching in cabbage are more often attributable to calcium deficiency or calcium "unbalance" than is commonly supposed. Recent reports on calcium deficiency in crops indicate that visible symptoms of deficiency are related to the exchangeable calcium in soils rather than to the calcium concentration in the soil solution. B. W. Doak (1) notes that in pasture soils in New Zealand the yield of herbage is more closely correlated with the exchangeable calcium content than with the pH of the soil. In a study of calcium deficiency in carrots A. W. Purdy (2) grew the plants in artificial media containing clay saturated to varying extents with calcium. Growth increased with the supply of exchangeable calcium up to 6 milli-equivalents per 100g. Larger proportions increased the calcium uptake of leaves but not that of roots, and also failed to increase the yield or phosphorus content of roots or leaves. In a similar investigation with spinach, R. A. Schroeder (3) finds that 6 milli-equivalents of calcium per 100g. of soil marks a similar maximum limit for the intake of phosphate.

Interrelationships between the calcium and phosphorus nutrition of roses examined by J. G. Sealey and O. W. Davidson (4) suggest some kind of compensatory system involving these two nutrients. Maximum growth and flowering was attained with phosphorus 100 and calcium 50 p.p.m. in the sand-clay medium, although with phosphorus 100 and calcium 5 or phosphorus 10 and calcium 50 p.p.m. adverse effects were very small. Increase in the calcium concentration to 400 p.p.m. with phosphorus at 100 or 5 p.p.m. produced very inferior growth and flower production. W. A. Albrecht and N. C. Smith (5) also recorded a reciprocal relationship between the intakes of calcium and phosphorus by legumes and non-legumes, the phosphorus intake being favoured by increase of degree of saturation of the soil with calcium.

Since a deficiency of calcium usually involves restriction of root growth it may be that the apparent interdependence of calcium and phosphorus in plant nutrition is centred around the mechanism of intake.

Relationships between calcium and potash nutrition in lettuce are examined by A. S. Hunter, S. J. Toth, and F. E. Bear (6) in soils in which the Ca/K ratio was artifically varied. Growth is normal throughout the range of ratios 1-100 : 1, but yields are maximum with a ratio approximately 1 : 1. In the range 1-4 : 1 the Ca/K ratio in the plant closely paralells that in the soil. A sharp decline in yield is associated with certain limiting contents of calcium and potassium in the plants, viz., calcium more than 2 per cent., potassium more than 1 per cent., and Ca/K ratio more than 4.

Among other observations of the influence of calcium on plant growth may be noted that of R. A. Schroeder (7) on pea nodulation, which appears to be directly related to the exchangeable calcium of the soil, more nodules being formed in plants of high than in those of low nitrogen content, irrespective of the level of supply of calcium. The beneficial effects of calcium salts on the germination of tomato seed are examined by W. A. Albrecht, the action being attributable to calcium nutrition rather than to pH.

References

(1) *New Zealand J. Sci. Tech.*, 1941, *22, A*, 263.
(2) *Proc. Amer. Soc. Hort. Sci.* (1939), 1940, *37*, 799.
(3) *Ibid.*, 1941, *38*, 482.
(4) *Ibid.* (1939), 1940, *37* 967.
(5) *Proc. Soil Sci. Soc. Amer.* (1939), 1940, *4*, 260.
(6) *Soil Sci.*, 1943, *55*, 61.
(7) *Proc. Amer. Soc. Hort. Sci.*, 1942, *41*, 375.

(Abstracted from the section on "Soils and Fertilizers" by A. G. Pollard, Reports of the Progress of Applied Chemistry for 1943, issued by the Society of Chemical Industry, London.)

BIOLOGY AND AGRICULTURE IN THE POSTWAR WORLD*

BY

DR. ROBERT F. GRIGGS
National Research Council

Biologists have not measured up either to their opportunities or to their responsibilities in contributions to the war effort. It is highly important for the public welfare and for the welfare of biologists that this situation be improved. There are many clear signs that the biological arts and sciences are going to assume a much more important rôle in public services than they ever have before. It is important that we biologists be able to perform this increased service that we should be rendering.

For the first time in history food is being used as an instrument in national and international policy. Food policy as it is now being formulated by the Interim Commission of Food and Agriculture set up by the Hot Springs Conference of the United Nations is the best device yet brought forward for preventing future wars.

How far the recommendations of the Interim Commission will be put into practice it is not now possible to say. But I believe it certain that some sort of food policy will be adopted by the civilized nations. Some policy will in fact have to be adopted. Food production in the United States has increased much more than in the first World War. It is up about one third over 1939. It has increased even more in Britain. There is good reason to suppose that further increases rather than recessions will occur. We shall have food surpluses—if we are to consider them surpluses—much greater than during the depression. In the face of the situation that is surely coming only two courses are possible: (1) we may either restrict production and put surplus producers on some sort of a dole, or (2) we may dispose of the surplus at low prices. There are many millions of people who never get enough to eat who need all the food that can be produced. How can the food be got to them? To do so we need to make only one simple decision which is analogous to a decision made by our forefathers here in America.

In the old days only the well-to-do could afford an education. Our forefathers decided that it was necessary for the public good that each child go to school. If now we similarly decide that it is in the public interest that everybody have enough to eat, food will be provided for all.

As I pass to the more personal problems of our group, I point out that the servicing of any food policy whatever is going to call for great enlargements in the biological and agricultural sciences.

Now at the threshold of the postwar world, we must ask ourselves what kinds of professional services will be rendered by the group which we loosely call biologists. Clearly enough we have not done very much in the war. The most striking feature of the whole war effort from the point of view of biologists is the fact that we were not enabled to render anything like the services which were needed and which we were anxious to give towards the war effort. Why was this so?

The essence of professional service is that it should provide what clients need—not necessarily what they want. Clients are acutely conscious that they need help, but they seldom have any clear conception of what they need from any of the professions. That is one's primary reason for calling a doctor. All that is required of a patient is that awareness of need prompt him to consult a doctor. A competent physician will do the rest.

Here is the first of our problems. We must educate the public, of which the Army is part, to realize what it needs from us. The Army had need of a vast amount of service from our sciences, but it wanted very little.

That is always the way with the Army, or, for that matter, with any organization. More than a year before the "bazooka" appeared in North Africa a friend told me that his organization was developing a portable weapon carried by two men which would do the damage of a cannon which had to be mounted on an automobile truck. But, said he, "The Army will have none of it". We all know the outcome. When the Army was finally convinced and took it up they were inordinately proud of it. Perfecting the weapon required perhaps less work than "selling" it to the Army. Educating the Army to its own need is a major part of war service.

We scientists do not generally appreciate that this is a perfectly expectable characteristic of human nature. You will recall the well-known occasion when George Westinghouse tried to sell air brakes to Vanderbilt, and the railroad magnate dismissed him with the remark that he "had no time to bother with damn fools." We who number so many teachers among us ought to know that education is a slow, difficult process which requires an expert staff, a systematic curriculum and careful organization throughout.

Why should we expect it to be different with the War Department? The thing to rejoice in and marvel at is not that new weapons were invented but that O. S. R. D. had the set-up and the funds to carry its ideas clear through to the battlefield.

Many important improvements in warfare were offered by the plant and animal sciences, but our groups did not have the organization to carry through or even to get the funds necessary to carry through.

I am reliably informed that $500,000 was spent for development work on a fungus project which could have been done by mycologists for $20,000, but the government agency in charge did not know where to turn for assistance. If one were to try to allocate blame for this waste he would

* Invitation paper before a joint session of Section G and the Botanical Society of America in Cleveland, September 13, 1944 (somewhat revised).

have to charge it not to the government, but to the patriotic mycologists who though anxious to help did not know that a professional organization was necessary to render effective assistance. If there had been a competent war committee in mycology, alert and able to give the time required to establish the necessary contacts and confidence in the competence of their "profession" the mycologists would, as they should, have made a tremendous contribution to the war and would have secured a recognition of the importance of their science, which is still a long way off.

It is interesting to observe that the plant pathologists, who deal with fungi as do the mycologists, but in a more limited way, could not handle the problem in question. They were in fact not aware of it until it was well on its way towards solution.

Yet the plant pathologists, together with the entomologists, had a very able war committee on crop protection which did one of the best war jobs in the whole field of the life sciences. Their committee, co-operating intimately with WPB, worked out a system of allocations and substitutions which provided an adequate supply of fungicides and insecticides through the period when all copper was sequestered for war uses. As an illustration of the amount of persistent education that was necessary to bring that about it is interesting to recall that on the first interview W.P.B. replied, "Oh, yes, we recognize that you must have insecticides and we will give you all the blue vitriol you need. But of course every ounce of copper will be used in weapons"—blissfully ignorant that blue vitriol is sulphate of copper.

A good illustration of "what it takes" to serve the War Department, or for that matter any part of the public, is furnished by the Ethnogeographic, Board. That board, headed by Duncan Strong, undertook to furnish the War and Navy Departments with all available information from travellers and from the literature about the geography, the peoples and the conditions in countries of interest to the military. It proceeded both to gather together all possible resources and aggressively to contact all officers in the Armed Forces responsible for furnishing this type of information to the field commanders. It won great acceptance and high appreciation from the Services, as it deserved to do. But it required a good many thousand dollars just to make available to the Army what was more or less common knowledge to the sciences concerned.

The devotees of the biological and agricultural sciences may, I believe, usefully consider the education of the public which has been carried out by the medical profession during the last generation. When I was a boy nobody thought of calling a doctor until he was bedfast. The result was that in many cases the doctor was not called until it was too late.

By a long and carefully planned course in public education the physicians have shown us that it is thoroughly advantageous for us to seek help from them at the first sign of trouble. This has been of even greater advantage to physicians than to patients. The change in the situation of the medical profession is very great, and very important for us to consider.

First and most important is that fact that the public is being maintained in far better health than was possible under the old regime. That is to say, the foundation of all the prosperity of the medical profession lies in the fact that it is rendering better service than it ever did before. Second, under this growing appreciation of our general need of medical attention, the number of physicians has doubled and quadrupled, and their average incomes likewise have doubled and quadrupled.

Clearly the job of the biological and agricultural sciences is similarly to educate the public as to what it needs in the way of service in our fields.

What biological services, now, does the public need? Very much as the old-time doctor could not have foreseen the services which his successors would render, so we in our sciences have no very clear vision of what we ought to be doing for the public. That, I think, is our greatest weakness, and every one of us ought to set his mind to work figuring out those ways in which in his specialty he could contribute most to the public welfare.

I shall content myself with only one illustration of what I mean—drawn from my own science, ecology. The ecology—the total ecology—of pastures and ranges is a matter which has been given comparatively little attention. It has been computed that in some of the western ranges the rodents consume more forage than do the grazing livestock. The insects may take as much as the rodents and domestic animals combined.

All the complex interrelations of forage plants, rodents, insects, predatory animals and domesticated livestock in pastures and ranges call for detailed and expert attention by large groups of specialists. At present there are no such people. We have plant ecologists who will study succession of vegetation on the pasture, and we have animal ecologists who will discuss the relations of the various animals present—but we have no adequate and comprehensive knowledge of the total ecology of pastures.

Moreover, all our knowledge of pasture ecology is general or, at least, it is expressed in generalizations. What is needed is very specific service on specific ranges at specific times.

Suppose for the sake of illustrating the point that our present knowledge of pasture ecology were an adequate foundation for management of pasture lands. We would be merely in the stage of progress where research could begin to be useful. In medicine the utilization of a research begins only after its publication when it is taken up and put into practice by physicians. But in ecology we drop a subject when we have successfully completed and published the pioneer research.

We ecologists naively hope that farmers and ranchmen will apply the findings of ecological research to their own lands. But no one would

expect that laymen could go far in the application of the results of medical research to their own ailments.

One can readily name half a dozen other types of practising ecologists whose service to the public would be decidedly worth while. Every ocean-going fishing vessel should carry an ecologist thoroughly grounded in oceanography. As it is now, the captain has to be ecologist as well as navigator and executive. Similar specialists in game management are needed in every considerable game-producing area. Consulting specialists in the control of soil erosion are needed in many areas fully as much as physicians to maintain the very existence of man on those lands. Billions of dollars would be saved annually by the services of a competent corps of farm management specialists available to individual farmers. Our present extension system provides only a minute fraction of the services needed, that is to say, of the services which would return to the landowner substantially more than it would cost to provide them.

It is important to realize that our professions would grow and prosper irrespective of whether such services were provided on a fee basis, as are physicians and lawyers, or from public funds, as are county agents. There are advantages and disadvantages of each type of compensation for the consultants. The relative merits of these systems do not enter into our present concern. The important consideration for us now is that the public welfare would be vastly promoted by the development of ecological services of the type mentioned.

One type of such practising ecology is already in existence though in a small and comparatively inadequate way—the forester advising those types of forest management that will bring the largest returns in the long run. What ecologists need to do is to take organized thought toward the development of similar avenues of service in other branches of the science.

Ecology is merely an example. Every other biological and agricultural science has similar calls for service and every one ought to have an energetic promotion committee to bring to realization its opportunities—no, rather, its duties—to serve the public.

In the biological sciences we have no considerable body of men comparable to the practitioners of law and medicine, and among practitioners I include in this sense the lawyers and physicians who are supported by public funds as well as those who set their own fees. It is we, in fact, who deserve the familiar jibe levelled at a proverbial Mexican Army. At present we are all trying to be generals!

We complain that whereas medical research is generously supported, research in the biological sciences receives only niggardly stipends. It is often said that the difference is due to the directness of application of medical research to human welfare. This can not be the real reason, for much research in the biological sciences brings as direct benefactions to its recipients as the services of a physician. Hybrid corn, enabling a man to produce 30 per cent. more with the same effort than he could with the old varieties, certainly confers as direct a benefit as the physician who by his advice might perhaps be able to keep the farmer well, actively producing and out of the poorhouse for, let us say 30 per cent. more years than his father. But the services which plant and animal breeding can render to agriculture and through agriculture to all of us have yet to be imagined by most people.

I believe that the better support of medical research is due more to the fact that there is a large body of physicians able to understand technical researches and to interpret them to the public than to any other reason. Certainly the American people will support biological researches as soon as they are convinced of what these will do for human welfare. The best way to gain support for research in the biological sciences is to develop a large body of intelligent and influential practitioners who would demand that some one solve the problems they met in their daily service. An unsympathetic but, I fear, discerning critic has charged that while the chemists, physicists, geologists and other scientists have gone to work in the service of mankind, the biologists are still children picking flowers and catching butterflies!

Psychology, the latest science to join the group practising directly for the public, has achieved that degree of service only during our generation. I would call your attention to the twin facts that the public now finds very useful, psychological procedures of which it was entirely ignorant a few years ago, and that psychologists at the same time have become more numerous, better paid, more useful and, may I add, they have developed vastly greater self-respect than they had a generation ago. Moreover, the pure science of psychology has made such progress in these decades as could not have been imagined by our fathers.

The problem before us, then, is to create more jobs in the biological sciences by enlarging their services to the public welfare. This is not a thing which can be done in a day but requires continuous effort and calls for a never-ending programme of public education.

Our scientific societies ought to undertake it. Consider how long the physicians have been engaged in this sort of activity, and how it continues to pay dividends both to the public in the way of longer and better living and to physicians in opportunities for more service.

The primary need of our sciences is for permanent organizations of skilled people to carry on this work of public education. I believe that biological and agricultural scientists could make no better investment than to supply the funds for such organization.

People tell me that the income of biologists is too small to permit them to assume the expense of effective organization. I reply that just because they are underpaid, biological scientists need all the more to undertake this work. It is the one thing which they cannot afford to skimp.

I will admit, however, that permanent effective organizations are more than some of our scientific specialities could undertake, and the obvious answer is for related fields to combine for this purpose. We have among us illustrations of the beginnings of such combinations of societies. One is the Federation of American Societies for Experimental Biology. A second is the Inter-Association Council of Societies Concerned with Animal Disease and Production. Other areas in which combination is obviously called for are in the fields of plant disease and plant protection in which the plant pathologists and entomologists could well develop their common services to the advantages of themselves and the public. Another is the various societies concerned with the other manifold applications of ecology to the public service, which are suggested in the illustration given above.

Now, as I talk, I suspect that a large number of my audience are feeling that I am not talking about them or even that I am not talking about biology as they know it, since I have spoken only of applications. The majority of you—of biologists in general—are teachers, as I am myself. We are devotees of pure science and we commonly look down on applied science. And that is the way I also was brought up. But we are acutely conscious of the fact that there is no adequate outlet for the students we produce. This under present circumstances, is inevitable except in special cases.

Can you imagine the majority of lawyers, physicians or engineers being teachers?

The function of the teacher in those fields is merely to train the recruits necessary to keep the professions up to strength. It is perfectly clear that the biological sciences can never grow and prosper until they develop services to the public comparable to the other professions. And when this is done the numbers who will be required for teaching will increase to proportions little dreamed of to-day. Even for the men, therefore, who love pure science and desire to devote themselves to it, opportunities will greatly increase when we develop our services to the public. Think what has happened in psychology.

The fact that so high a proportion of the devotees of the biological sciences are teachers is merely another way of saying that we have not arrived at the status of professionals.

There is no such thing as a profession of biology. Within the Division of Biology and Agriculture of the National Research Council there are, indeed, already two well-developed professions. Each has a well-marked *esprit de corps*. Each maintains the type of professional organization which I advocated above, and each renders valuable services directly to the public: namely, the foresters and the veterinarians.

Any thoughtful consideration in the light of fact makes it clear that there can not be any one profession of biology, that professional development in our field must come in the various segments of biology. There is clearly room for a profession of bacteriology, of ecology, of farm management, etc.

This brings me to the question which I suspect the sponsors of this programme expected me primarily to consider: namely, What can be done toward the the consolidation of biology and agriculture?

All analysis makes it clear that progress must be made primarily by those different groups among us which will ultimately develop into professions. For twenty years attempts have been made to build all biologists together into some sort of a single unity. As you know very well, they have not achieved any notable degree of success despite much effort by devoted men in that cause.

The reasons for the failure are clear enough. In essence, there is not now the foundation necessary on which to build such a federation of all the biological sciences. That is not to say that there is not need for and a place for common action of all our biological groups.

I find that the National Research Council can be of use, separately, to foresters, veterinarians, agronomists, bacteriologists, soil scientists and so forth, but it has to serve these different groups alternately. Their interests, their techniques and their objectives are too diverse to permit them to work together in common assembly.

We could not set up any single War Committee in Biology and Agriculture. There was plenty of good-will and no jealousy to interfere. But every problem that came up was concrete and called for consideration by experts in one segment of our field only. For instance, dairymen could not help much with the development and allocation of insecticides any more than plant pathologists could help with strictly mycological problems or foresters with problems in nutrition or bacteriologists with the shortage of animal feed.

If I may revert to an analogy used on a previous occasion,* I fear that we, who have been concerned with cultivating the growing plant to which we may liken the tree of the biological sciences have made the error, commonly fallen into by inexperienced gardeners, of looking only at the top of the tree we are seeking to nurture without paying sufficient attention to the roots. In short, our biological sciences are not as yet well enough rooted in service to the public to support the type of organized federation which we would all like to see.

Any serious examination of the roots of the biological tree will, moreover, reveal, I believe, that it is not growing from one tap root but has, rather, a branching root system spreading in many directions. Our present concern should be to strengthen each of these various roots, particularly those which show signs of vigorous potentiality and those which are reaching into large areas of unoccupied ground. If this is done, and not before, I suspect the top of the tree will blossomforth in a Federation of all the Life Sciences that would be surprisingly satisfactory to those who recognize the essential unity of all living things.

**Science*, 96: 2503, December 18, 1942, Vol. 96, No. 2503, pp. 545-551.

Reprinted from *Science*, Vol. 101, N.S. No. 2619, 1945, pp. 235-239.

MISCELLANEOUS NOTES

Maintaining Soil Fertility in Citrus Cultivation

Mulches

In Florida as in Bermuda, the system of soil management followed is planned to add humus to the soil, conserve moisture and fertility, and maintain the soil in the best condition for plant growth. Professor Hardy in a critical review of Bermuda's soils (*Agri. Bull. Bermuda*, 18; 21, 1939) stated that the nutrient status is probably seldom or never a limiting factor in crop production in Bermuda, but rather the moisture relations of the soil. Soil fertility in Florida's sandy soils depends almost entirely on the humus content for base exchange capacity. This is one reason why clean cultivation throughout the year, once widely practised in Florida has now been abandoned. A dust mulch is maintained in the Fall months which is kept harrowed throughout the dry season. When the summer rainy season begins, cultivation is discontinued and a volunteer growth of weeds and native grasses allowed to spring up. This cover-crop grows during the summer, and the following October or November is disked under to add humus to the soil. Cover crops are rarely left standing through the winter on account of fire hazards. Leguminous crops are objected to since they harbour pumpkin bugs, sometimes a serious pest on citrus trees.

A mulching system is used successfully by some Florida citrus growers. Until the grove comes into good bearing, clean cultivation in combination with cover crops is practised, and after that time the weeds and grasses are allowed to grow the year round. The weeds are mown once or twice a year and left on the ground as a mulch. Fine fruit is produced by this system on moist hammock soils. On the rocky limestone soils of Dade Country, Florida, where cultivation with harrows is impracticable, all of the tillage is performed with hoes. The weeds and grasses are cut off frequently at ground surface and left as a mulch.

The use of mulches in the form of composts derived from coppice and other wild plants has been used in the Bahamas and Florida to control nutritional deficiencies in citrus such as zinc and manganese. Evidently the native plants are better able to obtain these minor elements from the soil than are the citrus trees.

Mulching the ground around the trees and other plants is always a good procedure when they are young. After they have attained sufficient size to shade the ground over the root area, mulching may be dispensed with in the home-garden but best results will follow where its use is retained.

The most readily available mulching material around the home garden is cut grass or leaves raked up from the yard. A grass mulch in order to be effective must be fairly thick. A very satisfactory substitute in Florida has been found in sawdust or planings from a woodworking mill. This adds a neat appearance to the home yard. One to two inches of this material is sufficient depth. The possibilities of sawdust mulching in Bermuda should most certainly be investigated.

Farmyard Manure

In Florida the opinion at one time prevailed that farmyard manure was injurious to citrus trees and that its use frequently resulted in die-back. It is true that stable manure may have a bad effect especially on trees growing in light soil, when it is applied in large quantities, and in the absence of sufficient copper in the soil. When applied in small quantities, however, it is one of the best fertilisers for citrus trees. Besides adding humus, especially necessary in Bermuda, farmyard manure promotes beneficial bacterial action in the soil. It is also an aid in correcting deficiencies of minor elements in the soil.—(Reprinted from *Fruit Culture in Bermuda*, Report by J. M. Waterston, 1944, pp. 42-44.)

* * *

The Allied Rubber Position *

THAT the United Nations have been saved from a most serious situation with regard to supplies of rubber by the sudden collapse of Japan, is made clear by an article in the July issue of "The Industrial Chemist". While the United States supply of synthetic rubbers up to 1945, exceeded to some extent the requirements (the figures given are Requirements 976,000 tons, Supply 1,020,000 tons), the supply of crude rubber was inadequate (Requirements 157,000 tons, Supply 123,000 tons). In the words of the Rubber Director's report "crude rubber" had once again become "the most critical of all strategic materials".

It will be seen, however, that while the supply of crude rubber falls short of the amount required, yet, the actual requirements are themselves considerably reduced from pre war levels. Thus in 1941 the United States consumed as much as 790,000 tons of crude rubber. If the figures for natural rubber production centres are examined it will be seen that British Malaya (production 651,500 tons) and the Dutch East Indies (651,000 tons) both exceed very greatly in production the amounts needed to meet the present deficit. Hence with the liberation of these areas (plus such sources of supply as Burma, North Borneo, Sarawak and French Indo China) even allowing for damage done to the plantations by the enemy, the supply of crude rubber becomes once again fully adequate. Thus the danger envisaged by the author of the article who states "the position for 1945, and particularly for 1946, must be extremely difficult unless during 1945 the Allies succeed in occupying and obtaining supplies from one of the larger rubber producing areas still in Japanese hands" would seem to have been averted in the nick of time.

* *The Industrial Chemist*, July, 1945, p. 383-388.

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

The Extraction of Protein Foods for Plant Materials

MEANS of increasing the supply of protein, foods for both the human and animal dietaries, by new and unconventional methods, were described in this paper by Dr. R. E. Slade, Dr. D. J. Branscombe and Mr. J. C. McGowan.

There will never be enough meat, cheese, eggs, and fish to supply the world's needs of protein. Plenty of suitable protein exists, but it is associated with too much fibre, starch, or oil, or else it is unpalatable.

Traditional methods of meat production are not very efficient in converting grass and other vegetable protein into animal protein. During its lifetime the ox lays down only 9 per cent. of its protein intake as meat. The annual protein production of an acre of grass—600 lb.—when fed to fattening stock yields only 59 lb. of protein in the form of meat (390 lb. of beef). A milch cow is a rather more efficient converter, yielding about 15 per cent. of its lifetime intake of protein, while the 250 gals. of milk produced per acre represents some 90 lb. of protein.

The account given by the authors of the several methods of increasing the yield of protein from vegetable crops by mechanical and chemical extraction instead of using biological processes showed that substantial progress has been made in the last few years. Improving on the single grass milling process of the Hungarian Ereky, after the last war, Dr. J. H. Birkenshaw, at Jealott's Hill, had produced a press cake from the cell fluids which recovered 50 per cent. of the original protein. By coagulating the protein by heat under slightly alkaline conditions the astringent flavour was eliminated. J. C. McGowan had adapted Birkenshaw's screw press to large-scale production, and a sugar cane mill had given the same protein recovery efficiency with a greater throughput.

If each farm were provided with its own plant 200 lb. of protein could be concentrated from the grass acre's 600 lb. yield in the form of grass curd, or press cake, as well as 72 lb. of milk protein recovered from the fibre and liquor by-products of the process which could be fed to dairy cattle. This total of 272 lb., however, simply meant that "we have done nothing much more than the wheat plant does on one acre of arable land," for wheat grain from one acre contains 269 lb. of protein.

In an alternative method extraction explored by McGowan, Guant and Marmoy minced grass was hydrolyzed with the protolytic enzyme papain, which made soluble 50 per cent. of the total nitrogen for expression as a liquid. This could be evaporated to give a product resembling meat extract. The process was not regarded as practicable and the large quantities of papain required were not available in wartime. Work was therefore switched to recovery of protein from imported ground nut cake, which could be made into human food if the fibre content were reduced. The Ardil process—extraction with alkali and precipitation with acid—was the result. The plant to deal with any great tonnage was not, however, in existence. The importance of the work was not so much the success of the Ardil process but the attention it drew to the problem of supplementing the cereal and potato diet of a large proportion of the world's population with a foodstuff very rich in protein and relatively free from fibre made by processes more efficient than the traditional method of producing meat, milk, cheese and eggs.—(*Chemistry and Industry*, No. 15, p. 117, 1945.)

* * *

Lignin

LIGNIN, a by-product of pulp and paper mills that has long been regarded as "the largest waste in industry," is now found useful with fertilizers to add humus and organic matter to depleted soils, according to Robert S. Aries, research associate at Yale University. This new use of lignin, he says, is an "extremely important discovery, because of the tonnage involved." Lignin is an organic substance which, with cellulose, forms the chief part of woody tissue. In addition to 2,000,000 tons of lignin now discharged annually by mills into streams and rivers, he asserted, sawmills and other woodworking plants throughout the country "can readily make available another 10,000,000 tons of wood waste which can readily be incorporated into fertilizers." "As a result of present-day experiments, lignin may assume an important part in this nation's soil-building and conservation program. It will be a 'wealth from waste' movement, since lignin at present pollutes the nation's rivers; as fertilizer, it will definitely aid in providing higher land values and richer soils." The part played in soil improvement by using lignin with fertilizers is largely to supply organic matter. "If lignin is used on presently fertilized soils which need humus and organic matter, it is estimated that the efficiency of these soils would be raised about 20 per cent.", he said. —*Science*, Vol. 102, No. 2637.

THE subscription to *Tropical Agriculture* is six shillings per annum, post free, Trinidad currency, to all countries within the British Empire or seven shillings and sixpence, post free, Trinidad currency, to all other countries. Subscriptions can commence at any time during the year.